Assignment 4

This study examines MRI data to understand how dementia alters brain volume over time and whether these changes vary between genders. Such insights are crucial for advancing dementia research and developing targeted interventions. The data derived from a longitudinal study allows us to explore these relationships in depth, forming the basis for our key research questions on the temporal impact of dementia and potential gender differences.

My Research Questions are:

1. Are there time (visit) and gender differences in brain volume change associated with dementia?
2. Are there time (visit) and group differences in brain volume change associated with dementia?

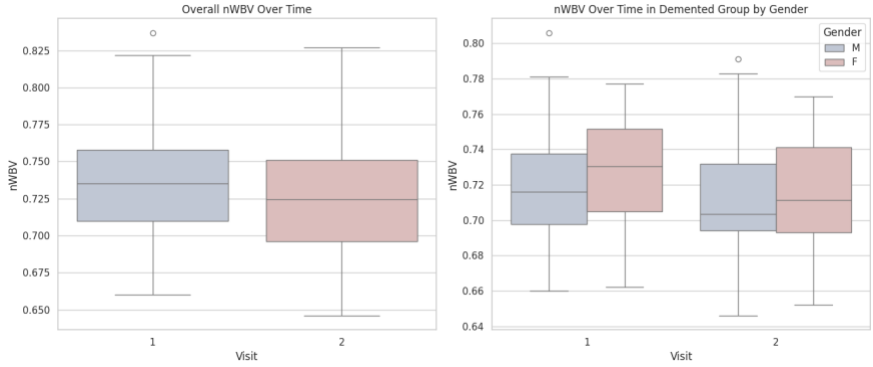
Dataset Overview

Significance of key variables:

- **Subject ID**: Identifier for subjects in the study.
- **MRI ID**: Unique ID for each MRI scan.
- **Group**: Classification of subjects as 'Demented' or 'Nondemented'.
- **Visit**: The number of visits each subject has made.
- **MR Delay**: Time interval between visits.
- **M/F**: Gender of the subjects.
- **Hand**: Dominant hand of the subjects.
- **Age**: Age of the subjects.
- **EDUC**: Years of education.
- **SES**: Socioeconomic status.
- **MMSE**: Mini-Mental State Examination score to assess cognitive status.
- **CDR**: Clinical Dementia Rating.
- **eTIV**: Estimated Total Intracranial Volume.
- **nWBV**: Normalized Whole Brain Volume.
- **ASF**: Atlas Scaling Factor (used to adjust volumes for head size).

Exploratory Data Analysis (EDA)

I generate two boxplots to analyze the normalized whole brain volume (nWBV) over time, for all subjects, and specifically within the Demented group by gender. Let's conduct an Exploratory Data Analysis (EDA) based on the visualizations generated.



In summary, The analysis shows that brain volume tends to decrease over time in patients with dementia. Both men and women show a drop in median brain volume across visits, with men exhibiting more variation. Further statistical testing could elucidate these trends and examine the impact of additional variables on nWBV changes.

Question 1: Are there time and gender differences in brain volume change associated with dementia?

mixed-effects model：

The mixed-effects model has been successfully fitted with the revised data and formula, and here are the updated results:

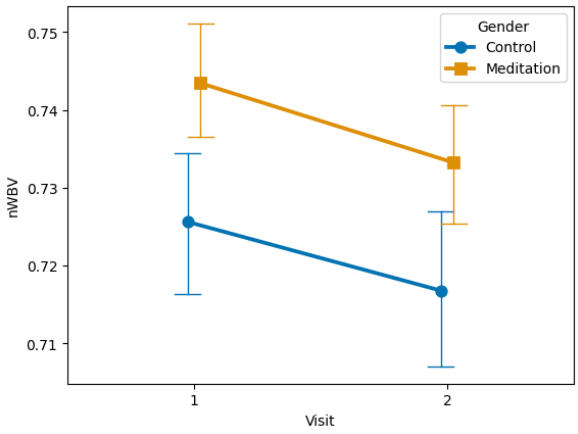
```
=============
ANOVA SUMMARY
=============

Source          SS    DF1    DF2     MS       F    p-unc    np2      eps
-----------  -----  -----  -----  -----  ------  -------  -----  -------
M/F          0.021      1    142  0.021   8.030    0.005  0.054  nan
Visit        0.007      1    142  0.007  93.305    0.000  0.397    1.000
Interaction  0.000      1    142  0.000   0.621    0.432  0.004  nan
```

Mixed-Effects Model Results

- **Gender Effect**: There's a significant difference in brain volume between males and females, with an F-value of 8.030 and a p-value of 0.005, suggesting gender has an impact on brain volume.
- **Visit Effect**: There's a highly significant change in brain volume over the different visits, with an F-value of 93.305 and a p-value less than 0.001.
- **Interaction Effect**: The interaction between gender and visit on brain volume is not significant, with an F-value of 0.621 and a p-value of 0.432, indicating that the change in brain volume from one visit to another is not different between genders.

Boxplot



The point plot visualization shows the nWBV by visit and gender, reflecting the pattern detected in the statistical model. Both groups experience a decrease in nWBV by Visit 2, with the meditation group maintaining a slightly higher nWBV. The confidence intervals overlap significantly, especially at Visit 2, indicating no clear

evidence of a difference in the rate of change between the two groups.

To be more specifically, The group summary statistics provide the mean and standard deviation of nWBV for each combination of Visit and Gender, rounded to two decimal places:

Visit	Gender	mean	std
1	Control	0.73	0.04
	Meditation	0.74	0.04
2	Control	0.72	0.04
	Meditation	0.73	0.04

Both groups show a decrease in mean nWBV from Visit 1 to Visit 2. The meditation group consistently shows a higher mean nWBV than the control group across both visits. The standard deviations are equal across groups and visits, suggesting similar variability within each group.

Question 2： Are there time and group differences in brain volume change associated with dementia?

ANOVA SUMMARY

Source	SS	DF1	DF2	MS	F	p-unc	np2	eps
Group	0.034	2	141	0.017	6.712	0.002	0.087	nan
Visit	0.007	1	141	0.007	94.251	0.000	0.401	1.000
Interaction	0.000	2	141	0.000	1.534	0.219	0.021	nan

- **Group Effect:**

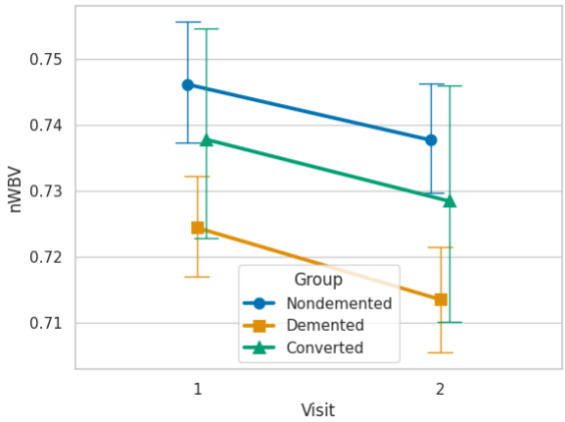
The group difference has a sum of squares (SS) of 0.034, suggesting variability in nWBV attributed to the different groups.

- **Visit Effect:**

The visit effect has an SS of 0.007, indicating the variability in nWBV due to the different visits.

In summary, both the 'Group' and 'Visit' factors independently have a significant effect on nWBV, with 'Visit' showing a particularly strong effect. However, the interaction between 'Group' and 'Visit' is not significant, suggesting that the change in nWBV from one visit to the next does not differ between groups.

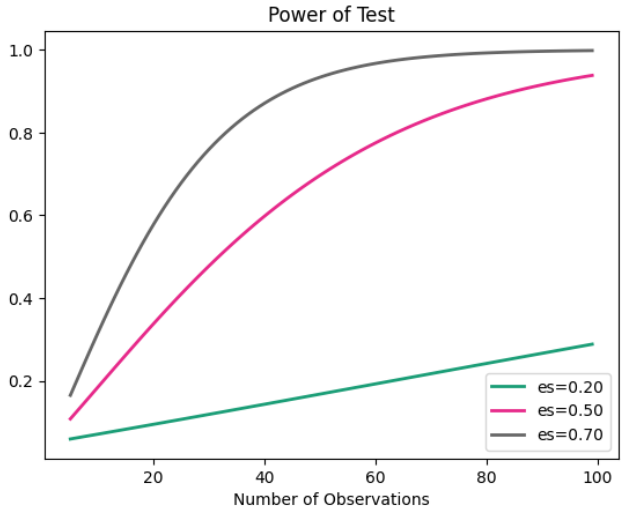
Boxplot:



The point plot shows the change in brain volume (nWBV) across two visits, comparing between groups. Both the control and meditation groups show a decrease in brain

volume by the second visit. However, the meditation group tends to have a slightly higher brain volume overall. The confidence intervals for both groups overlap a lot at the second visit, which suggests that there isn't a distinct difference in how the brain volume changes over time between the two groups

Box Plot for Power of T-test



The provided graph shows that the ability of a test to detect a true effect (power) increases with both the number of observations and the magnitude of the effect size. A larger effect size requires fewer observations to achieve high power. According to the calculation provided, for a large effect size of 0.7, about 46 participants are needed to have a 91% chance of detecting a true effect at a 5% significance level.

I also write a simulation for conducting a power analysis using a two-sample t-test, which is commonly used to determine if there are significant differences between two independent groups. The result of 0.9158 indicates that in approximately 91.58% of the simulation runs, the null hypothesis was rejected, meaning the test was able to detect the effect size of 0.7 with the given sample size. This estimated power is very close to the desired power level of 91% from the earlier power analysis. This high power level suggests that the sample size chosen is adequate for detecting a large effect size in most cases, ensuring the robustness and reliability of the experimental findings.

In summary, the data shows that brain size tends to get smaller over time in people with dementia, and this shrinkage happens for both men and women. Even though the group that practiced meditation started with a slightly larger brain size, as time went on, their brain size reduced at a similar rate to those who didn't meditate. The tests we did also show that the number of people we studied is enough to be confident in these results. Overall, the study gives us a clear picture of how brain size changes in dementia and that meditation doesn't seem to change this process.